DOI: https://doi.org/10.1128/jmbe.v22i1.2623
JMBE Journal of Microbiology & Biology Education

COVID-360: A Collaborative Effort to Develop a Multidisciplinary Set of Online Resources for Engaging Teaching on the COVID-19 Pandemic†

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The COVID-19 pandemic has challenged undergraduate instructors and students in an unprecedented manner. Each has needed to find creative ways to continue the engaged teaching and learning process in an environment defined by physical separation and emotional anxiety and uncertainty. As a potential tool to meet this challenge, we developed a set of curricular materials that combined our respective life science teaching interests with the real-time scientific problem of the COVID-19 pandemic in progress. Discrete modules were designed that are engaging to students, implement active learning–based coursework in a variety of institutional and learning settings, and can be used either in person or remotely. The resulting interdisciplinary curriculum, dubbed "COVID-360," enables instructors to select from a menu of curricular options that best fit their course content, desired activities, and mode of class delivery. Here we describe how we devised the COVID-360 curriculum and how it represents our efforts to creatively and effectively respond to the instructional needs of diverse students in the face of an ongoing instructional crisis.

INTRODUCTION

During the course of an academic career, an instructor's confidence in their pedagogical approach and technique typically grows. This comfort and mastery was completely upended by the COVID-19 pandemic in the spring semester of 2020 when the majority of colleges and universities in the U.S. transitioned from in-person to online teaching and learning. For some, the pandemic created a sense of anxiety and uncertainty due to its inescapable presence in both the news and society in general. For others, it changed their academic routines, especially in cases where instructors and students were barred from their on-campus offices and classrooms. Many students lost on-campus employment, had to work part-time, or had to increase their work hours to support their families amidst growing unemployment. Moreover, home life was also dramatically impacted, as both students and instructors needed to take on additional child or sibling care responsibilities. The impact of COVID-19 has therefore been debatably the most pervasive and destabilizing event to occur in the lifetimes of both students and instructors.

If instructors were lucky in March of 2020, they were given a week or possibly two to transition their courses from face-to-face delivery to an online format. For many, this was a new mode of delivery, as only 46% of instructors had previously taught an online course (1). In this uncertain and anxious context, many instructors transitioned previously created course content online and completed the semester remotely without any significant changes to content or delivery. While expert online educators were no doubt a valuable resource to their colleagues, many instructors were non-experts, simply trying to cope with the need to learn multiple new technologies, alter how they delivered content, and reimagine how they could develop student skills in an online learning environment.

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Received: 19 January 2021, Accepted: 25 January 2021, Published: 31 March 2021
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†Supplemental materials available at http://asmscience.org/jmbe

On top of these challenges, many instructors recognized the potential for students to become disconnected in the online learning context and sought to incorporate new ways to effectively engage students (2).

Several groups of instructors, recognizing this need, collected best practices being used within the life science education community and shared these resources via professional scientific societies (3). While these efforts were helpful, the need for advanced instructional materials that could be effectively delivered online was so great that additional materials were needed. We therefore worked collaboratively to create a multidisciplinary curriculum that would address student and instructors' needs while also focusing on the underlying biology of the current worldwide pandemic.

COVID as context: using the pandemic to develop effective classroom modules in the life sciences

The authors of this paper chose a similar approach to the necessity of adapting our courses. Recognizing both the opportunity presented by COVID-19 to present core scientific and societal concepts in the context of a significant "real world" event and the need for novel ways to engage students with lessons that could be delivered online, we chose to create materials for our courses that incorporated the biology of SARS-CoV-2 and the COVID-19 pandemic. Some of us employed these COVID-related resources for the remainder or entirety of the academic term following the online transition, others devised one or several new modules that related to upcoming course content, while others adapted previously developed materials to have a new COVID-related focus. In each case, we chose to respond to the new reality by using the public health crisis as a mechanism for engaging students more deeply in our courses while still achieving our courses' original learning objectives. We coupled this new focus with active learning strategies, including case studies, analysis of research articles, creation of research protocols, virtual laboratory experiments, and data analysis. All of these strategies have been proven to be effective at student engagement regardless of the class's mode of delivery (4–6).

While this current events topical approach certainly required additional work to implement, it had several distinct advantages. First, it allowed us to directly engage with the questions that our students were developing as they themselves tried to relate their previous coursework to a virus that was having a massive impact on their lives. We took advantage of the unusual opportunity presented by the pandemic to teach about the virus and the pandemic itself rather than beginning with traditional disciplinary content and then trying to build engagement. Second, this approach allowed us to model for students the perspective that the COVID-19 pandemic was a problem that could be understood and addressed by science. Scientists have the knowledge and tools necessary to help understand the virus, identify potential treatments, and develop effective new vaccines. In a time of great uncertainty, this is a reminder for students that science builds upon centuries of prior work and that the tremendous amount we already know provides clear starting points and paths forward for investigating and ultimately understanding this new virus and its effects. Finally, despite the extra work of creating new curricular materials, as scientists we were intellectually fascinated by this new pandemic virus and wanted to learn more about it ourselves! Sharing our curiosity with students and modeling engagement in life-long learning is itself another valuable teaching tool.

COVID-360: a collaborative approach to curriculum design

The intricate nature of the COVID-19 pandemic provides a unique opportunity to illustrate the importance of using a cross-disciplinary lens for examining scientific and social challenges. In our work, we realized how interdisciplinary science and active learning strategies could be combined to give a 360-degree view of COVID-19 (Fig. 1). Despite the fact that each of our courses was dedicated to a particular discipline (biochemistry, immunology, genetics, synthetic biology, etc.), we were able to demonstrate to students the relevance and overlapping nature of that content to the current pandemic. Shortly after the transition to online learning, we began to share ideas and teaching materials among ourselves so that we could offer students a more multidisciplinary view of the SARS-CoV-2 virus and the resulting pandemic. Over the summer of 2020, we pooled all of these materials into a multi-faceted series of curriculum modules that provide a 360-degree examination of the virus and pandemic; thus, we termed this set of materials "COVID-360." We focus here on the process of collaborative curricular development rather than the content of the curriculum itself; the full set of curricular materials will be available on CourseSource (https://www.coursesource.org) for public dissemination (in revision). We collectively used the current pandemic as a sandbox in which to bring together interactive methods for online instruction with pedagogy focused on current events. What resulted demonstrates to students how the concepts and techniques they are learning in their courses can be directly applied to societal events.

As mentioned above, the impetus for this project came from the quick transition to remote learning during the spring 2020 semester and the continuation of this mode of instruction as this article is written in the fall of 2020. The pandemic provided a unique opportunity to generate inquiry-based teaching materials that had their context grounded in a topic like COVID-19 that would be relevant for students to explore in real time. In other words, the pandemic promoted the use of situated learning by inclusion of real-world relevance to the curriculum and contextualization of learning, addressing a well-described educational challenge related to selection of content (7). Novel, virtual,

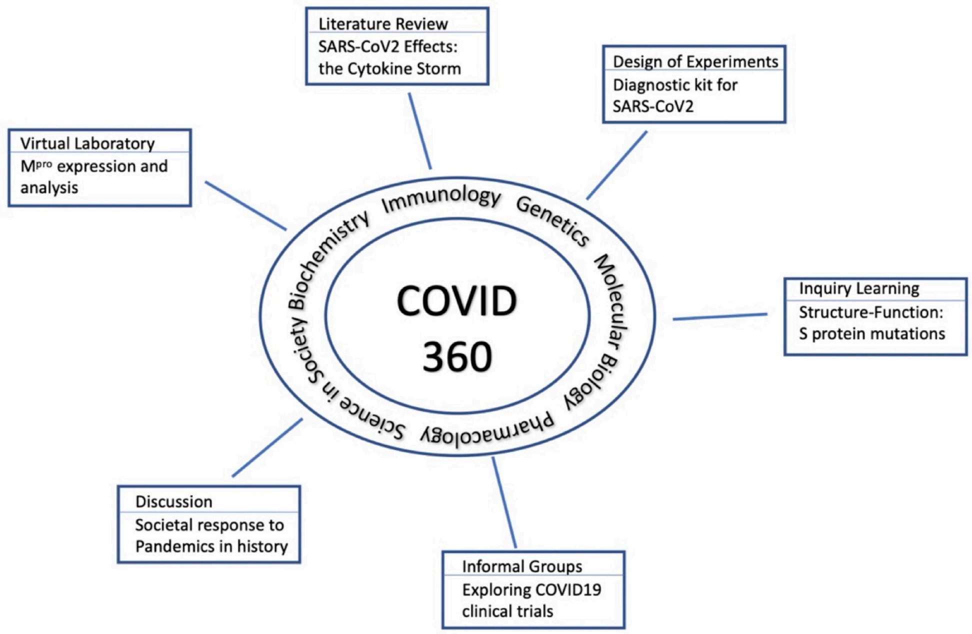

FIGURE 1. Graphical representation of the interdisciplinary nature of the COVID-360 curriculum collection. Illustrated in each branch are specific examples of active learning activities that can be used by themselves or in combination to generate a curriculum tailored to the needs of specific instructors.

innovative teaching strategies and curriculum modules were needed not only for our own courses, but also for dissemination across the greater education community so that they could fill the curricular need felt by faculty at a wide range of institutional types (R1s, PUIs, community colleges, minority-serving institutions, etc.). The faculty leading this effort are collectively leaders of many networks and innovations focused on science pedagogy which allowed us to both be aware of faculty needs and to disseminate materials widely.

Considerations for the design of COVID-360

Several principles were important to us in the design of this curriculum. First, we wished to use learning objectives for each biological subdiscipline that have been established by the relevant professional societies as essential for undergraduates (8). In considering our COVID-focused curriculum, we used the following overall learning objectives : 1) Students will gain an improved understanding of the COVID-19 pandemic by looking at how different scientific disciplines approach study of the topic; 2) Students will develop their abilities to work and research in a self-directed manner in their consideration of COVID-19; and 3) Students will develop skills and knowledge in their study of COVID-19 that will facilitate their understanding of key foundational principles in multiple scientific disciplines. Using a backwards design approach from these learning objectives, we developed a set of 25 modules for undergraduate courses in the molecular life sciences that are ready to integrate into existing courses (Table 1) (9).

Overall content areas covered by COVID-360 include biochemistry, molecular biology, immunology, genetics, pharmacology, and the role of science in society. We focused on these scientific disciplines because they are the ones most amenable to contextualizing their fundamental principles within the "real world" situation of the pandemic in a way that would be meaningful to students. To better address the diverse needs of students and differing learning contexts, the lessons provide flexibility for use either synchronously or asynchronously as well as in-person or remotely. Furthermore, both lecture and laboratory materials are represented, helping to fill the substantial need for materials which can be implemented in remote lab courses and which teach both investigative skills and the process of science.

To develop the modules that comprise this curriculum, we started with a list of broad curricular themes and learning outcomes that we planned to cover in our fall 2020 courses. Next, we identified COVID-19–specific themes that would tie in with some of the learning outcomes. Additionally, we brainstormed whether there were existing materials that we had already developed and vetted in our previous courses that could possibly be adapted to focus on COVID-19. A set of ideas of how to frame parts of our courses through a COVID-19 lens emerged, leading to a list of potential curricular modules. We then engaged in discussions about both the content and pedagogical techniques used in each module under consideration. We selected a subset to further develop by focusing on diversity of content, the ability of modules to work together, and the inclusion of activities that used a broad set of active learning strategies to enhance student engagement in the virtual classroom. We spent time refining our materials, compiling them, and subjecting them to peer review within our faculty group. Each module was evaluated for clarity of directions, whether the resources provided

TABLE 1.
COVID-360 curricular modules.

Module Number	Discipline	Type of Activity (Active Learning Strategy[a])	Class Type and Time Needed	Specific Topic
1	Systems biology	Primary literature analysis **(Inquiry Learning)**	2–3 hours in class and/or homework (in-person or virtual)	Protein interactions of SARS-CoV-2 and how they can be used to predict useful drugs against the virus
2	Synthetic biology	Primary literature analysis **(Brainstorming)**	50- to 75-minute lecture class (in-person or virtual)	Construction of the SARS-CoV-2 genome from chemical precursors and how this technology can aid in pandemic response
3	Science and society	Historical analysis **(Large Group Discussion)**	One or more 50- to 75-minute lecture classes (in-person or virtual) depending on depth of discussion	Contextualization of COVID-19 against other significant instances of disease influencing society
4	Medicinal and Pharmaceutical Chemistry	Primary literature analysis; research and analysis skills **(Case Study)**	2–3 hours in class and/or homework (in-person or virtual)	Identify chemical and biological aspects of a drug and its target using Dexamethasone as a case study (with ties to the physiology of inflammation and cytokine storm)
5	Medicinal and Pharmaceutical Chemistry	Small group project; database search; concept map; oral presentation **(Small Group Discussions)**	One or more 60-minute lecture classes (in-person or virtual) depending on optional self-pacing and class discussions	Explain the different phases of clinical trials and why each is necessary. Specific clinical trials currently relevant to COVID-19
6	Medicinal and Pharmaceutical Chemistry	Scientific media analysis; research skills; presentation **(Group Evaluations)**	One or more 60-minute lecture classes (in-person or virtual)	Analysis and short presentation of a science media article about current topics of COVID-19 in the medical and pharmaceutical industry
7	Immunology and virology	Case studies **(Case Study)**	50-minute lecture class	Broad to specific overview of the biology of SARS-CoV-2 and the impact on the immune response
8	Immunology and virology	Primary literature review **(Inquiry Learning)**	One to five 50- to 75-minute discussion classes (in-person or virtual)	Read, interpret, and analyze data about SARS-CoV-2 from the broad immune response to directed therapies
9	Immunology and virology	Journal club presentation **(Oral Communication)**	One or more 50- to 75-minute discussion classes (in person or virtual)	Interpretation and analysis of a journal article about SARS-CoV-2 in a formal oral presentation
10	Immunology and virology	Mind/concept map **(Self-assessment)**	One to two 50-minute lecture classes (in person or virtual)	Introduction to the immunology of SARS-CoV-2 and terms related to the virus and COVID-19
11	Genetics	Computational activity **(Experiential Learning)**	50-minute lab (in-person or virtual)	Using phylogenetic trees to understand the molecular evolution of SARS-CoV-2
12	Genetics	Computational activity **(Experiential Learning)**	50-minute class (in-person or virtual)	Design a diagnostic kit for SARS-CoV-2
13	Genetics	Database activity; discussion **(Interactive Lecture)**	Two 50-minute classes (in-person or virtual)	Gene structure and expression of ACE2 and TMPRSS2 receptors and sex differences in symptom severity
14	Biochemistry	Computational activity **(Experiential Learning)**	2- to 4-hour computational exercise	Structural analysis and substrate specificity of SARS-CoV-2 main protease
15	Biochemistry	Computational activity **(Experiential Learning)**	2- to 4-hour computational exercise	Structural analysis and domain structure of SARS-CoV-2 spike protein
16	Biochemistry	Experimental design **(Brainstorming)**	1- to 2-hour in-class or homework exercise	Primer design for bacterial expression of viral proteins
17	Biochemistry	Interpretation of wet lab data **(Experiential Learning)**	One or two 1- to 2-hour in-class or homework exercises	PCR cloning and protein expression of SARS-CoV-2 main protease

18	Biochemistry	Interpretation of wet lab data **(Experiential Learning)**	One or two 1- to 2-hour in-class or homework exercises	PCR cloning and protein expression of SARS-CoV-2 Spike protein fragments
19	Biochemistry	Interpretation of wet lab data **(Experiential Learning)**	One or two 1- to 2-hour in-class or homework exercises	SARS-CoV-2 main protease kinetics assays
20	Biochemistry	Experimental design and interpretation of wet lab data **(Inquiry Learning)**	One or two 1- to 2-hour in-class or homework exercises	Antigen immunoassay design and interpretation
21	Biochemistry	Mind/concept map **(Self-assessment)**	20–30 minutes of in-class instruction and 1–2 hours homework	Terms related to SARS-CoV-2 and COVID-19
22	Biochemistry	Video creation and computational activity **(Hands-on Technology)**	1 hour of instructional time with 3–4 hours asynchronous work	Analysis of the domain structure of the spike protein
23	Biochemistry	Small group research project **(Small Group Discussions)**	2–3 hours of homework time	Potential therapeutics for COVID-19
24	Biochemistry	Primary literature analysis **(Inquiry Learning)**	3–4 hours independent or in-class time	Analysis of CE-spike protein plus video interview with paper authors
25	Biochemistry	Primary literature analysis **(Inquiry Learning)**	3–4 hours of homework time	Analysis of naturally occurring mutations in the spike protein during the pandemic, and analysis of how research results are presented to the public

Each module is designed to be used either by itself or in combinations with other modules depending on the needs of the instructor.
[a]https://crlt.umich.edu/active_learning_implementing (Prepared by Chris O'Neal and Tershia Pinder-Grover, Center for Research on Learning and Teaching, University of Michigan)

were complete enough for easy adoption by other faculty, relevance of content, and alignment with learning objectives.

We felt it important that the COVID-360 curriculum be modular in nature; this allows instructors to select from the modules as if selecting from a menu so that they can best fit the precise educational needs of their class. We also wanted modules that could be delivered in combination and sequentially; the close ties between many of the topics covered by the distinct modules allow instructors to create interlocking sets of materials. For example, a biochemistry or molecular biology module could be paired with one on synthetic biology or ethical considerations of pandemic research. Perhaps most excitingly, the "360" nature of the curriculum allows for an instructor to effectively demonstrate to their students how deeply connected the scientific disciplines are and how a scientific problem of the magnitude of this pandemic requires collaboration between multiple scientists operating in multiple fields to come to an effective solution.

We also focused on the alignment of the activities with the learning goals of each of our existing courses. The introduction of modules from the COVID-360 curriculum replaced other pre-existing activities, and we made sure that the overarching learning objectives were not compromised. We wanted the COVID-360 modules to help facilitate the transition to online teaching for all instructors, even those with limited experience. For each of the 25 modules, therefore, we provided a clear framework of the activity as well as instructor's notes and implementation suggestions for each activity and the time required for completion. This will help instructors to both select the module or combination of modules to use and deliver the modules themselves.

Importantly, the COVID-360 modules that we developed are designed to be effective for distance learning yet also have the flexibility to be delivered either in-person or remotely. For each module, students can go through the lesson and work on the assignment(s) either synchronously or asynchronously, and often there are options for faculty to decide whether a lesson is to be done individually or in small groups. The modules come with suggestions for background reading and a list of prior knowledge needed as well as how aspects of the lesson fit with the principles of scientific teaching: active learning, inclusive teaching, and assessment (10). Both the active learning and inclusive teaching components are especially important when incorporating assignments with distance learning (11).

COVID-360 in action

We have supplied four examples of lesson modules written in the style of the COVID-360 package as supplemental materials. These lessons give a sense of the way in which we designed group assignments that are appropriate for classes in biochemistry, pharmacology, or other biomedical disciplines, as well as how individual modules can be used either by themselves or in combination with others.

An example of how COVID-360 modules were combined in order to be used for remote or hybrid teaching is briefly described here for a junior-level biochemistry lecture course (Table 1). Here, a concept map was initially used to drive the class to understand the common concepts of COVID-19 and to start conversations on the biochemical and molecular biology of the infection (Module 21). A deeper scientific dive was created when students were given a series of biochemical questions on the disease and asked in groups to prepare videos answering the questions for the class. This was followed up with a robust discussion board and independent worksheets using the student-generated videos (Module 22). The molecular biology of reverse transcriptase and molecular tests (Module 23) were used to focus on the early semester concepts on nucleic acids. After amino acids and protein structure were introduced, rather than transition to the traditional hemoglobin or antibody structure/function discussion, the class examined the structure and function of the spike protein using an interview with the author of a recently published paper on the S protein (Module 24). In the upcoming semester, the instructor plans to supplement this work to highlight the novel mutations of spike protein and relate these to the molecular function and viral outcome. At the end of the term, students were asked to apply their knowledge to interpret a series of social media and press articles for their bias and validity (Module 25). This allowed for a complete integration of many of the COVID resources without the material being a side topic or distraction.

COVID-360 modules for active learning

Throughout most of 2020, students were inundated with information about how to stay safe during the pandemic from a diverse set of sources, including news pieces featuring local, state, and federal officials. Furthermore, students have also received emails and other forms of communication from their academic institutions as well as their instructors who are worried about the health and wellbeing of both their students and themselves. This overload of communication about safety measures, along with restrictions imposed by governments and academic institutions, may lead to what is now known as "COVID fatigue" (12–15). Yet, despite all the information students are receiving, little of it helps them to understand the pandemic from a scientific perspective. Students taking science courses have the advantage of being capable of understanding the ongoing situation in greater depth and can even help to disseminate results from ongoing research efforts to their communities in a way that can be commonly understood. The teaching modules in the COVID-360 curricular package may stimulate student interest in scientific concepts and their societal implications through an interdisciplinary and evidence-based scientific exploration of SARS-CoV-2 that complements what students may have learned about the pandemic from popular news pieces. The hands-on and discussion-based nature of the COVID-360 modules render them effective regardless of the mode of delivery (laboratory, classroom, or remote). For instance, an activity that involves the construction of phylogenetic trees of several *Coronaviridae,* adapted from Newman *et al.* (16), was effectively delivered in an upper-level Genetics course that, prior to the shift to remote instruction, regularly met face-to-face in a computer lab. This module could seamlessly be adopted in a distance-learning context either as an instructor demonstration or an online student-directed activity. Initial anecdotal evidence suggested that this module was well received among students. However, more work is needed on systematic assessment of the materials across courses and institutions.

Similarly, following the shift to remote learning, online discussions about the reported symptoms of COVID-19 infection were supplemented with demonstrations and assignments that used database explorations of the viral receptor ACE2 in human tissues (e.g., Human Cell Atlas, GTEx). In addition, our COVID-360 activities include a series of COVID-19–related laboratory experiences and specific experiments suitable for biochemistry and genetics/molecular biology laboratories (Modules 11 to 13 and 17 to 19 in Table 1). These lab materials are especially powerful as the lab activities themselves center on analysis and study of SARS-CoV-2 proteins; the curriculum provides students with real experimental data which can be analyzed in a remote setting in situations where lab courses need to simulate experiments.

The active learning nature of the COVID-360 modules promotes equity and inclusion at a time when we are facing new inclusivity challenges in the online environment. The anxiety of using new tools and the uncertainty surrounding the health of students, instructors, and their families has not dissipated as we write this piece in the fall of 2020, and the extension of campus closures and online course delivery may increase these feelings yet further. In this new environment, students may be uncertain about how well they are learning the material. Several of the activities can be used as asynchronous formative assignments; providing this type of ongoing feedback can increase students' confidence in both synthesizing complex scientific material and learning remotely. Using the materials in an asynchronous format can minimize student stress during a challenging time while allowing instructors the opportunity to devote time during online meetings to answering questions that the students formulated during the activity. Alternatively, those same selected activities can be delivered synchronously, initiating discussions within the classroom meeting time when the students can directly address their questions to the instructor. Notably, the majority of the activities are flexible and can accommodate different class sizes and be performed by small groups of students, thus allowing direct peer interactions, which in turn helps students stay connected to one another and promotes inclusive educational practices.

CONCLUSION

The onset of the COVID-19 pandemic necessitated the rapid development of educational resources that would contextualize the pandemic for students. Thus, we are still in the process of fully assessing the efficacy of these pedagogical tools and making adjustments to the tools as necessary. This can be the most challenging part of instructional mode transitions, such as the ones initiated by the COVID pandemic (17). In particular, we are interested in understanding how these modules are helping students to better grasp the specific events happening around them and whether the modules and learning activities give students perspective on what they can do as scientists and as members of society to mitigate the pandemic. The process of working together and developing a set of interdisciplinary materials in direct response to current events has been an invigorating and inspirational experience. It has also made us consider the overall efficacy of the "360" model as a means of producing materials in relation to other pressing scientific and societal issues. One could imagine developing a package of interdisciplinary teaching tools surrounding the climate crisis, race and social justice, and other topics that will require multidisciplinary understanding and approaches if effective progress is to be made. While we do not have resources in the COVID-360 package representing perspectives from psychology, sociology, or media studies, it is not hard to envision continuing to use this model to produce pedagogical resources that would introduce these and other disciplines into "360" treatments of other issues with a scientific component. Notably, instructors of different classes within the same program will be able to adopt different modules to achieve programmatic objectives, while demonstrating curricular coherence to their students. We are hopeful that members of the biology education community will take an interest in this set of pedagogical tools and help us in the implementation and assessment of these modules.

SUPPLEMENTAL MATERIALS

Appendix 1: Four representative examples of COVID-360 curricular materials

ACKNOWLEDGMENTS

We thank our fellow faculty and students who accompanied us in the transition to online teaching and learning and the students whose work with this curriculum has helped us to refine the materials. The authors have no conflicts of interest to declare.

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